

SOUND CONTROL

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The Architect and His Clients' Ears

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An acoustical consultant should be called in at the schematic design stage of any large or acoustically complex project, but it is still necessary for the architect himself to have a sound grasp of acoustical principles and to apply these to all of his structures.

BY ANITA LAWRENCE

Acoustical design considerations should play a part in every building, and this will become even more important in the future. More numerous and more powerful machines and appliances are used in every building type, and this usually implies that more noise is created.

Some of the most "modern" machines are products of the Dark Ages with regard to their noise-generating capacity, and a data-processing room today often has noise levels typical of a factory. At the same time, each new lightweight material or construction system that comes onto the market reduces the chances that a building might have "in-built" acoustical protection in the form of masonry walls and massive concrete floors.

Fortunately, there are many ways in which an architect can control the acoustical environment of his buildings, providing that he considers this aspect as part of his initial brief. Some of the more important factors of noise control are outlined here.

In "free space," i.e., in the absence of reflecting surfaces, sound pressure levels are reduced by 6 dB (decibels) for each doubling of distance from a single sound source. (A reduction of 10 dB corresponds to an approximate halving of the loudness of a sound.) Thus the first defense against noise is to locate a building as far as possible from major noise sources.

In practice, of course, reflecting surfaces such as the ground and other buildings are present, and the reductions obtained are less.

When traffic noise is the main problem, as is often the case, it is found that the average level is reduced by only 3 dB for each doubling of distance from the road, although the peak levels, which are due to individual vehicles passing, follow the 6-dB rule.

The next step is to consider the acoustical requirements of each space; some areas will be quiet and some noise producers. To a certain extent the degree of sensitivity to noise depends on the use of the space. Noise is produced due to the operation of normal activities. For example, a bedroom is noise-sensitive whereas a

workshop is noise-tolerant. On the other hand, an auditorium is sensitive to outside noise but may also be a noise producer.

Since walls and floors designed to provide good sound insulation tend to be expensive, it makes sense to group the quiet rooms and to separate them as much as possible from noise producers. Noise-tolerant spaces may be placed between a noise source and a noise-sensitive area to act as a shield, thus reducing the sound-insulating requirements of dividing construction elements.

Two types of sound propagation in buildings must be considered: through air and through the building fabric. Sounds such as speech, music and radiated noise from machines travel through air, and through intervening solids, to the listener. Other sounds such as footsteps and machine vibrations originate in solid materials and travel through the fabric of the building, finally radiating airborne sound to the listener.

In general, the more changes in the medium of propagation of the sound, the greater will be the reduction in transmitted energy. The most relevant physical properties of the media are their density and elasticity. Thus when airborne sound is to be reduced, the insulating medium should be massive so that the sound energy is transferred with difficulty into the solid and again into the air on the other side.

If the sound is solid-borne, the insulating medium should be lightweight and compressible so that the energy has difficulty in transforming from a rigid solid into the insulating material and back into the solid on the far side. Wherever

The author: Mrs. Lawrence is in charge of the Graduate Diploma in Architectural Acoustics at the University of New South Wales, Australia.

the sound-propagating medium provides an uninterrupted path between source and observer, little reduction of energy will occur.

This reasoning can be translated into practical terms by considering two adjoining rooms, one containing noise source and the other being noise-sensitive. The airborne sound from the noise source will create a sound field in the source room—the average sound level depending on the acoustical power of the source and on the total absorption in the room (a doubling of the total sound absorption reduces the average level by 3 dB).

Sound waves impinge upon the wall and floor between the rooms, and if they are massive and airtight, most of the energy will be reflected

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back into the source room. On the other hand, if the dividing wall or floor is of lightweight construction, most of the incident energy will be transmitted into the "quiet" room.

It is most important for an architect to understand the extent of sound leakage through small openings in otherwise good insulated construction. For example, if more than 10 percent of a wall consists of unglazed openings, the overall sound insulation will not exceed 10 dB, however good the performance of the remainder. Small cracks around doors, skirting ducts at the base of partitions, dry joints, etc., have a disastrous effect on sound insulation.

A common source of sound leakage in commercial buildings is through suspended "acoustical" ceilings, if the partitions are only taken to the suspended ceiling level. Sound waves pass through the suspended ceiling, bounce off the structural slab and pass back through the ceiling to adjoining rooms. It is now possible to obtain sound-attenuating suspended systems so that the room-to-room attenuation by the ceiling path is as good as the direct attenuation through the partition.

The wall or floor between the two rooms is not the only possible path for sound energy. Flanking walls, floors, etc., will also be set into vibration and will transmit energy into the quiet room. The rated sound insulation value of a dividing element will not be obtained in practice unless the surface of the flanking construction is at least half that of the dividing element.

When the solid-borne sound is the result of impacts, the most efficient method of reduction is to provide isolation at the source. This may take the form of resilient machine mountings, or resilient floor surfaces if footsteps are the problem. Where it is necessary to use a hard-finished floor, the resilient layer should be placed between the wearing surface and the structural slab. The design of machine mountings should be in expert hands, as an incorrect choice can lead to amplification of the machine's vibration.

If the required sound attenuation between two rooms, or between the outside and a room, is very high (as in the case for broadcast studios), it may be necessary to resort to box-within-a-box construction. A completely separate structure is used for the quiet room, isolated all around from the remainder of the building; if it is not possible to provide separate foundations, the floor of the quiet room must be supported on vibration mounts. All service lines, ductwork, etc., must have resilient connections from the noisy to the quiet area.

Airconditioning systems are a prevalent noise source in buildings.

be located as far as possible from quiet areas, i.e., not placed directly above conference rooms, and the plant should be resiliently mounted to reduce solid-borne sound. The supply and return ducting should also be separated from the machines with resilient sections, and sound-absorbent linings or packaged attenuators are usually necessary.

It must always be remembered that sound travels just as readily against the air stream as with it and that the silencing of return air systems and exhaust ducts is just as important as in the supply system. Many otherwise satisfactory partitions are made virtually transparent acoustically by the insertion of return air grills.

Plumbing noises may also be reduced considerably by attention to design and detailing. When a fluid flows viscously (all the particles flowing smoothly in the direction of the stream), little noise is created. However, turbulent flow due to excessive velocities or abrupt changes of direction as well as cavitation (bubble formation) can be effective noise sources. In itself a pipe is an inefficient radiator of airborne sound, but if it is rigidly fixed to a large radiating surface such as a wall or floor, noise from it may become a problem. Solutions include careful design of pipes and valves and resilient pipe supports.

Architects frequently become confused by the unfortunately large number of units that are used in acoustical specifications; some of the more common rating systems, particularly those used in the United States, follow.

Noise Criterion (NC number) — This is a method of specifying an acceptable background noise level in a room. It was derived by L. L. Beranek* from experience in offices; and it is closely related to the ability of people to converse at different distances.

The ear is most sensitive to sound having frequencies from about 1,000 to 4,000 Hz (cycles per second); the most important speech components with regard to intelligibility also occur within this range. Thus the ability to understand speech depends very much on the level of the background noise in this frequency region, and this is often the most important criterion with regard to acceptable noise in an office environment. The lower frequencies do not effect intelligibility greatly, but if they are too loud, the noise level will be unpleasant.

A noise criterion is in the form of a curve specifying the maximum allowable noise level in each octave band from 63 to 8,000 Hz, e.g., NC 30 permits 57 dB at 63 Hz, 35 dB at 500 Hz, 28 dB at 4,000 Hz, etc. The lower the NC num-

* Revised Criteria for Noise in Buildings, Noise Control, Vol. 1, Part 1, 1957, pp. 1-12.

ber, the lower the acceptable noise level. All of the curves allow higher levels in the low frequencies and lower levels in the speech intelligibility frequencies.

The noise criterion specified depends on circumstances: NC 30 is suitable for private offices; auditoriums should have a lower criterion; and large offices or other areas where the ability to converse is not so important (or where the activity noise levels are unavoidably high) may have higher criteria specified.

Decibels — familiar units in acoustics — are used to measure sound pressure levels. However, one must be careful to note the type of sound measuring system used. A simple measuring system with a linear response to sound at all frequencies does not correlate well with subjective impressions of loudness because of the nonlinear sensitivity of the ear as mentioned above. If most of the sound energy is concentrated in the lower frequencies, an observer will judge it quieter than another sound of the same total energy concentrated in the higher frequencies.

Therefore, when making measurements related to acceptability by people, it is usual to incorporate a "weighting network" in the system which changes the response to a nonlinear one similar to that of the ear. The most commonly employed weighting is called the "A" scale, and the measurements obtained are designed as decibels A-scale (dBA).

The actual readings obtained are normally about 10 units above the corresponding NC number so that NC 30 is about the same as 40 dBA. However, if a dBA measurement is used to check compliance with an NC specification, it is normal to allow an excess of only 5 units, e.g., 35 dBA would comply with NC 30). The advantage of dBA is that a simple measurement may be made of a single number — and it may be made continuously in a monitoring system. NC numbers require eight separate octave bands to be measured, although this is often necessary for design and calculation work.

Sound Transmission Class (STC) — The airborne sound insulation of a wall, floor or other element varies considerably with the frequency of the sound. Generally, the insulation obtained increases with frequency. In the mid-frequency range the sound transmission loss rises about 6 dB per octave, i.e., per doubling of frequency.

However, at high frequencies the so-called "coincidence effect" occurs. At certain frequencies and angles of incidence, the projected wavelength of the airborne sound corresponds exactly with the bending wavelength of sound of that frequency in the solid. Thus the solid vibrates in phase with the incident wave and

becomes virtually transparent at that frequency. This effect is most important in lightweight forms of construction: Glass, plywood, gypsum board, etc., all exhibit coincidence transmission in the ear's most sensitive frequency region. The sound insulation of these materials shows a marked "dip" in this range.

The Sound Transmission Class is a reference curve designed to allow fair comparison between the airborne sound insulation provided by different forms of construction. The shape of the curve was determined considering the spectra of typical domestic and commercial noises and also the need to provide adequate protection in the higher frequencies.

The curve slopes upward at 3 dB per one-third octave between 125 and 400 Hz, at 1 dB per one-third octave between 400 and 1,250 Hz and is flat from 1,250 to 4,000 Hz.

A standardized test of the sound transmission loss of the construction in question is carried out and the results plotted on a graph. The STC curve is then fitted so that the average deficiency of the construction does not exceed 2 dB and so that the maximum deficiency at any band does not exceed 8 dB. The rating given corresponds to the value of the STC curve at 500 Hz when correctly fitted — the higher the rating the greater the insulation provided. Thus by specifying one number, the performance of an element over the whole frequency range is determined: the 8-dB maximum dip takes care of coincidence effect deficiencies as described earlier.

It must be remembered that the STC curve was derived mainly for commercial and domestic situations and may not necessarily give the most economical answers for other applications. In particular, a wall rated by this method gives insufficient low-frequency protection when the sound source is traffic.

Impact Noise Reduction — The insulation provided against impact sound is more difficult to measure since the airborne sound resulting from an impact on the floor above depends on the interaction between the impacting force and the floor itself. A standardized source of impact — the tapping machine — is used to excite the floor and the sound pressure levels in the room below are measured at different frequencies.

These results are again compared with a standardized curve, but in this case they should not exceed the reference curve since these are transmitted levels. The amount of shift up or down required for compliance with the reference curve may be expressed as $-X$ dB INR or $+X$ dB INR, as the case may be.

One final warning: Most acousticians seem to work on "limit" design principles; it is up to the architect to ask for a "factor of safety." □